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HUMAN FACTORS CHARACTERISTICS OF THE JOINT TACTICAL
FUSION TEST BED: FIELD TEST 467 RESULTS

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poorly because operators felt performance time was excessive and procedures were overly tedious. ✈



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HUMAN FACTORS CHARACTERISTICS OF THE JOINT TACTICAL FUSION TEST BED: FIELD TEST 467 RESULTS

Foreword

The Fort Hood Field Unit of the US Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research in a variety of areas related to the needs of the Army in the field.

The US Army is in the process of obtaining a wide variety of automated equipments in an effort to overcome its disadvantage in numbers compared to potential adversaries. As a part of this effort, the TRADOC Combined Arms Test Activity (TCATA) evaluated the Joint Tactical Fusion Test Bed-Army (JTFTB-A). The primary objective of the evaluation was to determine the capability of automated systems to perform selected functions anticipated for inclusion in automated intelligence analysis systems. To be of use, these future systems must aid the analyst in performing these functions both more rapidly and more accurately than with the currently employed manual methods.

This report describes the human factors evaluation of the JTFTB-A conducted as a part of the TCATA test. Questionnaires, interviews, direct observation and physical measures of the equipment and environment were employed. Where appropriate, the potential effects of the human factors characteristics on overall system performance are discussed. The results of this research have been incorporated into TCATA Test Report FT 467, Joint Tactical Fusion Test Bed-Army (JTFTB-A) Final Report, May 1982.

The research described in this report was performed by the Human Resources Research Organization (HumRRO) under Contract No. MDA903-79-C-0191. This research is responsive to the special requirements and objectives of RDTE Project 2Q263743A794, "Human Factors and Training Research in Military Organizations and Systems," FY 1981 Work Program.

HUMAN FACTORS CHARACTERISTICS OF THE JOINT TACTICAL FUSION TEST BED: FIELD TEST 467 RESULTS

Executive Summary

Requirement:

Automated systems increasingly are seen as a way for the Army to make up for its disadvantage in numbers compared with potential adversaries. An automated All Source Analysis System (ASAS) for intelligence data is one such system being considered by the Army. Because intelligence analysis is highly complex and largely subjective in nature with few well-defined procedures, the Army chose to evaluate the capability of automated systems to perform certain ASAS-related functions by means of a test bed. The Joint Tactical Fusion Test Bed-Army (JTFTBA) was the system employed for the evaluation. One of the objectives of the evaluation was to collect data on human factors aspects of the system. Although the stated objective only called for the "collection" of human factors data, an attempt is made in this report to relate these data to the presumed ASAS-related functions.

Procedures:

Interviews, questionnaires, direct observation and physical measurements were employed to obtain the human factors data. Each operator received a structured interview following training on the operator terminal. Items requested information about specific functions of the terminal and general opinions about the system as a whole. Human factors questionnaires were administered at the completion of training and again during the Command Post Exercise (CPX). These questionnaires covered safety, the adequacy of features and characteristics of the system, and physical complaints. Human factors specialists observed operators throughout the evaluation, and when possible and appropriate, conducted informal interviews to obtain a better understanding of any problems that occurred. Environmental measures were obtained in three locations, and physical measurements of the operator's station were obtained to determine conformity to published human factors standards.

Findings:

In general, operators felt that their performance with the system would be superior to their performance employing the manual methods currently used by intelligence units. They liked the speed with which some functions were performed and felt that the ability to perform a number of functions without the need for interaction with other analysts was highly desirable. Overall, the 78 individual functions performed using the keyboard were highly rated. However, operators strongly disliked the cursor controls (the cursor could easily be lost) and felt that the AGGREGATION, PURGE and TARGET DESIGNATION functions were too time consuming and tedious. They also felt that redraw times for the map (often 30 seconds) were excessive. The two other major complaints were that error messages were difficult to interpret, and that alerting for incoming messages was inadequate.

The terminal configuration failed to conform to published standards in a number of areas. Most notably, controls for several critical and frequently used functions were

located in areas which were difficult to reach. Also, both tall and short operators had difficulty in "fitting" themselves to the terminal. Finally, lefthanded operators felt the terminal was difficult to use as the writing area was on the right side of the terminal.

Noise levels in the vans were above recommended maxima for areas where voice and telephonic communications are required. Temperatures were below recommended standards but relative humidity was within tolerance. However, since the system was not configured for actual deployment, these measures can only serve as guides to designers.

Utilization of Findings:

The findings of this human factors research have been incorporated into TCATA Test Report FT 467, Joint Tactical Fusion Test Bed-Army (JTFTB-A) Final Report, May 1982, and will be used to design future automated systems, especially those performing ASAS-related functions.

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HUMAN FACTORS CHARACTERISTICS OF THE JOINT TACTICAL FUSION TEST BED: FIELD TEST 467 RESULTS

Introduction

Automated systems increasingly are seen as a way for the Army to make up for its disadvantages in numbers compared with potential adversaries. The early use of these automated systems occurred in the fields of weapons control and administration, but much of the recent development has been in the fields of Command, Control, Communications and Intelligence (C³I).¹ Such systems are intended to provide the commander with better ways to manage the tremendous amount of information available on the modern battlefield. Whereas the earlier systems were designed to solve well understood problems such as how to lay a gun on target, the C³I systems must deal with poorly understood problems where there are no well defined procedures or solutions.

One such system, the Joint Tactical Fusion Test Bed-Army (JTFTB-A), was evaluated by the TRADOC Combined Arms Test Activity (TCATA) from June through November of 1981.² The evaluation had four objectives. The primary objective was "to assess the capability of the JTFTB-A to perform selected ASAS-related (All Source Analysis System for intelligence) functions."³ Another objective, and the subject of this report, was to collect data on human factors aspects of the system. The remaining objectives were to collect data on operator training and to collect data on reliability, availability, and maintainability of the system. Although the stated objective only called for the "collection" of human factors data, an attempt is made in this report to relate these data to overall system functioning, especially to presumed ASAS-related functions. By doing so, it is hoped that this report will meet its primary objective -- that of providing guidance to designers of future C³I systems.

The JTFTB-A represented a change in direction by the Army in its approach to C³I systems. Earlier attempts had either tried to automate a large part of the command and control process in one system or had concentrated on a very small aspect of it such as fire control.⁴ The Tactical Operations System (TOS) attempted to automate the commander's full range of C³I functions. So many different functions were incorporated into this

¹Institute for Defense Analyses. Computers in command and control (TR 61-12). Washington, DC: Research and Engineering Support Division, November 1961. (DTIC No. AD 251 997)

²US Army Training and Doctrine Command Combined Arms Test Activity. TCATA Test Report FT 467: Joint Tactical Fusion Test Bed-Army (JTFTB-A) (RCS ATCD-8). Fort Hood, TX: Author, May 1982.

³Ibid.

⁴US Army Combined Arms Combat Development Activity. Architectural concept for 1985 for U.S. Army Tactical Command, Control, Communication and Intelligence (C³I) (ACNO 52686). Fort Leavenworth, KS: Author, 1978.

system that it did none of them well and the development efforts had to be discontinued.⁵ By contrast, the Tactical Fire Direction system (TACFIRE), which was originally planned as an element of TOS, concentrated on the limited problem of using an automated system to direct the division's artillery.⁶ This system is now fielded and being used successfully. Its usefulness is limited, however, because it does not have automatic information exchange either with the computer equipment at the battery level or with any high level systems.

The JTFTB-A represents an attempt to choose some of the best of both approaches.⁷ Like TACFIRE, it focuses on a small part of the command and control problem, the fusion of intelligence data. According to hearings in the US House of Representatives:

A tactical fusion center is a means of accepting intelligence and command and control data from many different sources and "fusing" them in a coherent, readable and understandable manner [sic] to display to a military commander what is happening on the battlefield so that the commander may decide what tactical options are available to him.⁸

By concentrating on the limited problem of fusing intelligence reports from various sources, both electronic and human, the JTFTB-A could be designed around procedures that had already been used in other automated systems and could be designed into a hardware package small enough to transport into the field.

The JTFTB-A was not designed with the notion that such a system would totally supplant the current manual intelligence operation which supports the corps commander. Rather, it was designed to handle many of the routine, time-consuming functions that take much of the intelligence analyst's efforts.⁹ This leaves the analyst free to handle the higher-level cognitive tasks of deciding what the enemy's order of battle is and what

⁵US General Accounting Office. Tactical operations system development should not continue as planned (LCD-80-17). Washington, DC: Author, November 20, 1979.

⁶A. M. Haynes, P. L. LaPointe, H. L., Cooke, & J. A. Underwood, III. Tactical fire direction (TACFIRE) operational test III (TCATA Test Report No. OT 056). Fort Hood, TX: TRADOC Combined Arms Test Activity (TCATA), August 1978.

⁷P. T. Marston, A. L. Kubala, & R. G. Cooper. Human factors considerations in the battlefield exploitation and target acquisition (BETA) system: A preliminary evaluation (FR-MTRD(TX)-81-12). Alexandria, VA: Human Resources Research Organization, February 1981.

⁸US House of Representatives. Department of Defense Appropriations Bill, 1981 (HR 96-1317). Washington, DC: US Government Printing Office, September 11, 1980.

⁹C. A. Montgomery, J. R. Thompson, & R. V. Katter. Human processes in intelligence analysis: Phase I overview (Research Report 1237). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences, 1979.

the enemy commander intends to do.¹⁰ Thus, the JTFTB-A functions as a decision aiding system.¹¹ It allows the analyst to access the information it has stored in its data base about what the intelligence sources have detected. It presents this information to the analyst either graphically as a location on a map of the battlefield or as a report which can be displayed or printed. By providing a common data base, it allows several analysts to work on the same information and share their results very quickly. All of these features should allow the analyst to manipulate the information into a form conducive to evaluating the enemy's intentions and assets much faster and more accurately than with current manual systems.

All operator-induced data manipulations take place through the use of the interactive terminal. Because this interface is so important to successful operation, the bulk of the human factors data collection focused on this device. Since the system was a test bed, no operational concept had been developed. Hence, the research effort concentrated on those characteristics of the system that are likely to be a part of any future intelligence analysis system rather than those specific to JTFTB-A. For example, the configuration of the terminal keyboard is probably specific to this system, while the symbolic presentation of forces on a map-like situation display is a likely feature of any intelligence analysis system. Nevertheless, the terminal design was evaluated as it was felt that the information gleaned could be of use to designers of future systems.

The most important feature of the user-computer interface is the interactive dialogue.^{12,13} This dialogue consists of all the interactions that the operator has with the system to make it accomplish the required tasks. From the terminal, the elements are prompts, menus, forms to fill out, error messages, reports and map displays. From the operators, the elements are commands, menu selections, information for forms, positioning of the cursor, and free-text messages. If the dialogue characteristics facilitate communications between the user and the computer system, then the user should be able to obtain exactly what is wanted with a minimum of effort. To the extent that the dialogue does not facilitate the operator's job, the system may prove difficult to learn, difficult to use, and a source of physical and mental problems. Hence, an evaluation of the adequacy of the dialogue is essential and is given consideration in this report.

¹⁰R. G. Cooper, P. T., Marston, & A. L. Kubala. Human factors in automated C³I systems (Draft). Alexandria, VA: Human Resources Research Organization, March 1981.

¹¹R. C. Goldstein. The substantive use of computers for intelligence activities (MAC TM 21). Cambridge, MS: Massachusetts Institute of Technology, April 1971. (DTIC NO. AD 721 618)

¹²J. Martin. Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall, 1973.

¹³H. R. Ramsey & M. Atwood. Human factors in computer systems: A review of literature (Technical Report SAI-79-111-DEN). Englewood, CO: Science Applications, Inc., September 1979. (DTIC No. AD A075 679)

A recent concern with systems that have a Visual Display Terminal (VDT) using a cathode ray tube to present the information is the possibility of health hazards to the operators when operating the terminal many hours per day. Recent studies have reported that many VDT operators complained of various physical and emotional symptoms.^{14,15} The JTFTB-A operator's position is likely to require long hours under high stress at the display, so health problems are of concern in the system design and were considered in the human factors evaluation.

In order to put the results of this human factors data collection effort in perspective, it is necessary to understand how the JTFTB-A system is designed to work. As mentioned earlier, no formal concept of operations for the system had been developed. However, as the authors worked with the system, they were able to piece together a reasonable concept of operation from interviews with test and project office personnel and from the various technical documents provided by the contractors. A description of the system based primarily on those documents^{16,17,18} is presented in Appendix A and should be reviewed by readers of this report who are not familiar with the JTFTB-A system.

Methods, Analysis and Participants

Data Collection Methods

The human factors data for the JTFTB-A were collected using a combination of interviews, questionnaires and direct observation. The researchers observed the test bed operation and operator training from the time the system first arrived at Fort Hood, Texas, through the Command Post Exercise (CPX) which concluded the first year's evaluation. Informal interviews were conducted throughout the test with all of the test team members in order to learn more about the system. Additionally, all of the operators were formally interviewed during or shortly after their training, and questionnaires were given to them after their training and during the CPX. Each phase of the test was observed to

¹⁴M. J. Smith, B. G. F. Cohen, & L. W. Stammerjohn, Jr. An investigation of health complaints and job stress in video display operations. Human Factors 1981, 23, 387-400.

¹⁵L. W. Stammerjohn, Jr., M. J. Smith, & B. G. F. Cohen. Evaluation of work station design factors in VDT operations. Human Factors, 1981, 23, 401-412.

¹⁶TRW Defense and Space Systems Group. BETA operator positional handbook (CDRL A009, FSCM No. 11982). Redondo Beach, CA: Author, April 1, 1980.

¹⁷TRW Defense and Space Systems Group. BETA architecture and process flows (SS22-47B, FSCM No. 11982). Redondo Beach, CA: Author, September 28, 1979.

¹⁸TRW Defense and Space Systems Group. System specifications for BETA test bed (SY16-12-C, FSCM No. 11982). Redondo Beach, CA: Author, January 26, 1979.

see how the operators interacted with the test bed. Finally, the operator terminal was measured and photographed to determine how well it conformed to existing human factors engineering standards.

Operator interviews. Each operator received a structured interview (see Appendix B) after receiving training on the JTFTB-A terminal. It consisted of 101 items requesting information about specific functions of the operator terminal and general opinions about the way the system functioned as a whole. The first 43 questions dealt with function keys that controlled a single action, such as moving the cursor or deleting a character. The next 35 questions dealt with the more complex functions that typically started an interactive dialogue which tailored a function to a specific requirement. Examples of complex functions are CREATE QUERY and INPUT CONTROL MEASURES. For both simple and complex functions the operator was asked (a) "Have you used this key [function]?;" (b) "How much did you use it?;" (c) "How well did it work?;" (d) "What problems did you have with it?;" and (e) "How would you change it?" In some cases it was more logical to ask about a group of similar keys, such as the cursor positioning functions, so the questions were phrased in the plural. In most cases the answers to items (a), (b), and (c) involved only one or two words while answers to items (d) and (e) tended to be more elaborate. The last 23 questions of the interview dealt with the operator's opinions concerning the use of the system to carry out specific tasks, how the system might be changed, and overall impressions.

The interview was given either in a single session or over two days, depending on the operator's schedule and lasted from 30 minutes to two hours, depending on how much the individual had to say.

The first group of operators, trained in the summer, were in the process of using the system for the single function tests when they were interviewed, so they were asked separately about each of the 78 functions. The second group of operators, trained in the fall, did not have as much experience using the terminal, so after the first two operators were interviewed, an abbreviated procedure was developed. The operator was shown a diagram of the keyboard and asked to point out which functions he or she had used. As each function was indicated, the last four of the five questions listed above were asked for that function. After completing this portion, the operator received the same final 23 items as the first group. Although it was clear that the second group of operators did not know as much about JTFTB-A as the first group, this procedure seemed to produce about the same information while shortening the interviews considerably.

Human factors questionnaire. The operators were given a human factors questionnaire (Appendix C) the last day of each two-week training period and were asked to rate the quality of various system features. The areas covered by the questionnaire were controls, workspace, environment, graphics display, alphanumeric display, and safety. The items for all of the areas except safety were rated on a five-point scale running from 1 to 5. These values were labeled "very inadequate," "inadequate," "borderline," "adequate," and "very adequate," respectively. The items in the safety area referred to specific parts of the system which were rated as having or not having electrical, thermal, structural, mechanical, visual, or auditory safety hazards. It should be noted that the information on environment and safety were of limited value because the operator terminals were installed in a tunnel rather than in mobile shelters as they likely would be in a fielded system.

CPX questionnaire. The CPX questionnaire (Appendix D) was given to the operators on duty during each shift of the exercise. The data collection for this phase was designed not to interfere with the ongoing CPX operations. As a result, the questionnaire was not given at the same time during each shift and operators were occasionally missed. The questionnaire consisted of two parts: a rating scale and a list of health complaints. The first part had eight items which described major characteristics of the system and the CPX operations. These were rated on the same five-point scale used with the human factors questionnaire. The second part of the questionnaire asked the operators to state whether they experienced any of 11 common physical complaints. The complaint data were obtained at the beginning and ending of each shift, while the ratings were taken near the middle.

Direct observation. The human factors researchers were present for all phases of the test. They observed the operators learning about and using the various functions. These observations were supplemented with direct questions about what an operator was doing when this would not interfere with other parts of the test. Notes were taken both on what the operators did well and what problems they had. Note was taken of how they responded to equipment and software problems. When a situation arose where it was not clear what was going on at an operator terminal, both the test personnel and the support contractor personnel were questioned to determine what might be happening. This proved to be a useful procedure since many of the operators' problems with functions resulted from "bugs" in the system. It was difficult for the operators to know what to do when functions did not work as described in the training. After the observers had been with the system for some time, the operators and test personnel began volunteering human factors related information. This was particularly useful since there were never enough test personnel to cover everything that was happening.

Physical measurements. Many human factors engineering standards relate to the size and shape of equipment. The dimensions of the operator terminal were obtained to the nearest millimeter using a steel tape measure. These were compared with engineering drawings held by the support contractors to verify their accuracy. Discrepancies were resolved by making the measurement again. These measurements were employed to calculate the critical dimensions for this type of equipment referenced in published human factors engineering standards. The operator's position at the terminal was determined from photographs made of four operators whose height ranged from 56 inches (142 cm) to 76 inches (193 cm).

Environmental measures were obtained in the correlation processor, communications, and remote display system vans. Measures consisted of temperature, humidity, and noise levels. The wet and dry bulb temperatures were measured with a Psychron, Model 566-2 psychrometer (fahrenheit readings). Sound levels were measured with a sound level meter, Model 1565-B (General Radio), which conformed to ANSI S1.4 standards for a Type 2 instrument. The meter was calibrated with a Model 1567 sound level calibrator (General Radio) before each set of measurements. Both the sound levels and wet and dry bulb temperatures were measured in the same locations in a given shelter. Three locations were used in the correlation processor and two in the other shelters. A single set of measurements was taken on each of three separate days during the summer when the single function testing was keeping the processors operating. While the shelters were not specifically part of the test, the environmental conditions there might approximate what the operators would experience in a fielded version of the system. It was also known that

computer operators had complained about the conditions in the correlation processor during earlier tests, so it was desirable to get environmental measures for it.

Data Analysis

Due to the nature of the data collected, extensive analyses did not seem to be justified. Virtually all of the data except the physical measurements of the terminal and the environmental measures were completely subjective. Even though these latter measures are completely objective, they could only be compared with published standards to determine whether the system met these standards. The analyses conducted, and the decisions made concerning interpretation, are described below for each type of data collected.

Questionnaires. Descriptive statistics for each item in the questionnaires were prepared. A full tabulation including frequency distributions is presented in Appendix E for the Human Factors Questionnaire and Appendix F for the CPX Questionnaire. To provide meaning to these data, some arbitrary decisions had to be made. By consensus, the research staff opted for the following interpretation for all items rated on the "very inadequate" to "very adequate" scale:

- a. Desirable characteristics, controls or functions (adequate or higher ratings by 80 percent or more of the operators).
- b. Suspect characteristics, controls or functions (adequate or higher ratings by 70-79 percent of the operators).
- c. Problem characteristics, controls or functions (adequate or higher ratings by less than 70 percent of the operators).

Two other types of data were to be collected by questionnaire. Questions on potential safety hazards were included in the Human Factors Questionnaire. However, no hazards were reported. Questions on physical complaints were included in the CPX Questionnaire. These were simply tabulated for each day of the exercise. It was arbitrarily decided that any complaint developed during the exercise reported by 10 percent or more of the operators indicated a potential problem.

Interviews. During the interviews the operators were given considerable latitude in making their responses, so the interviewer and another member of the research staff coded responses to the questions about simple and complex functions using the scheme shown in Table 1. Disagreements in coding, though very few, were resolved through discussion. A full tabulation of the response codings is shown in Appendix G.

The interviews generated a large number of spontaneous comments from the operators. These were recorded, and will be used to amplify or clarify interpretations presented in the Results section.

Direct observation. No separate analyses of notes made while observing the operators was conducted. Items from these notes, like those from the interviews, will be used to justify or bolster the interpretations of other data presented in the Results section.

TABLE 1

**Coding Scheme for Responses to Items 1 through 78 of the
Human Factors Interview**

<u>Question</u>	<u>Value</u>	<u>Meaning</u>
Have you used this key?	0	No response
	1	Have not used
	2	Have used
How much did you use it?	0	No response
	1	Very little (1-2 times)
	2	Not much (3-5 times)
	3	A lot (more than 5 times)
How well did it work?	0	No response
	1	Unsatisfactorily
	2	Satisfactorily
	3	Well
What problems did you have with it?	0	No comment
	1	Negative comment
	2	Neutral comment
	3	Positive comment
How would you change it?	0	No comment
	1	Hardware change
	2	Software change
	3	Training change
	4	No change

Physical measurements. The physical measurements of the hardware and the environmental measurements were compared with applicable human factors engineering standards in MIL STD 1280,¹⁹ MIL STD 1472B,²⁰ and Van Cott and Kinkade.²¹ No standards could be found for some of the measurements obtained. Deviations from acceptable ranges were noted, and interview and questionnaire data were examined to determine what, if any, comments were made concerning items which failed to meet the standards. The data from all of these sources are reported and discussed together in the Results section.

Participants

A total of 41 soldiers were trained to operate the JTFTB-A terminals. Shown below (Table 2) are their military grades. Also shown are their Military Occupational Specialties (MOSS) (Table 3) and some general demographic information (Table 4). It can be seen that their military grades ranges from E2 through O2, and their MOSSs were in the intelligence or intelligence-related fields (with the exception of the lone 13F, Fire Support Specialist). About half of them had been in the military for less than three years and more than half had been working in their MOS for less than two years. Most were under 30 years of age and all had at least a high school level of education.

Results

As discussed in earlier, the human factors data collection effort focused on those functions and characteristics of JTFTB-A that were perceived as likely to be included in any future ASAS hardware/software system. Obviously, the findings regarding these functions and characteristics must be interpreted in light of the situation in which they were obtained. First of all, it must be remembered that no clearly defined operational concept or set of missions for the system existed. Hence, operator dissatisfactions with or perceived shortcomings of the system may have resulted from unrealistic expectations. Secondly, the level of operator training was undoubtedly below what would be expected for a fielded system in an operational setting. Not all of the 35 operators interviewed had used all of the system's functions, and in many cases where they had, they had done so only once or twice (see Appendix G). Therefore, familiarity with the system was less than desired. Finally, since the system was intended as a test bed, off-the-shelf hardware items were employed rather than items designed specifically for the functions incorporated in the system. Nevertheless, it was felt that operator opinions concerning the system as a whole, the functions performed, the man/machine interface, and the working environment would provide useful information for designers of future systems. Therefore, the discussion of the results is oriented along these lines and toward this end.

¹⁹US Department of the Army. MIL-STD-1280: Military standard keyboard arrangements. Author, January 1969.

²⁰US Department of the Army. MIL-STD-1472B: Human engineering design criteria for military systems, equipment and facilities. Author, December 1974.

²¹H. Van Cott & R. G. Kinkade (eds). Human engineering guide to equipment design (rev ed). Washington, DC: US Government Printing Office, 1972.

TABLE 2**Military Grades**

Military grade	Number of operators
E2	3
E3	4
E4	9
E5	7
E6	11
W1	1
W2	1
W4	1
O1	3
O2	1

TABLE 3**Military Occupational Specialties (MOS)**

MOS	Number of operators
Enlisted Personnel	
05G	2
05H	1
13F	1
96B	19
96D	6
97B	1
98C	3
98G	1
Warrant Officer	
964A	1
973A	2
Commissioned Officer	
35A	2
37A	2

TABLE 4
Demographic Information

Years	Number of operators
Time in Military	
0-3	21
3-6	6
6-9	8
9-12	3
12-15	2
More than 15	1
Amount of Experience in MOS	
1-2	27
2-4	6
4-6	4
6-8	3
8-10	0
10-12	0
12-14	1
Age	
Less than 20	7
21-25	13
26-30	16
31-35	2
36-40	2
41-45	0
46-50	1
Highest Level of Civilian Education	
12	19
13	7
14	5
15	1
16	7
More than 16	2

Total System

It seemed desirable to obtain some indication of how well a fielded system modeled after the JTFTB-A as a whole would serve the intelligence analyst's needs. Therefore, some items in the questionnaire were designed to assess global impressions of the system and much of the discussion during the interviews centered on this subject. Test personnel also contributed many comments on how the system might be used. Comments were recorded and will be reproduced in the following subsections as appropriate.

General utility. In question 97 of the interview (Would this system help or hinder you in doing your present job?), 54 percent of the operators made comments suggesting that the system would help them, while 26 percent indicated that it would hinder them. "Obtaining the desired information is easy if the operator is an intelligence analyst preferably with one year's experience," said one. Another said, "As a traffic analyst I can see where the enemy is and what he is trying to do. I can associate with the situation better when I view it on the graphic screen." One liked the direct access to the computer: "Entering information in the system is so much easier, you don't have to fight with a bunch of people." Another said, "The operator doesn't have to bug a lot of people for information, it's very easy." Others liked the speed: "It's much faster than manual -- it takes five minutes for information compared to two or three days manually." Negative comments questioned the appropriateness of this particular type of system and the difficulties of making it work in the field. Some operators were concerned that they did not know enough to use it. One warrant officer said, "We need somebody in the exercise with a million years of experience." The orange battlefield entity hierarchy (i.e., friendly units acting as the enemy) caused others problems, like the operator who could not work with it because he "did not know the range of our own artillery." Others could not get the information they wanted. For instance, they could not tell if a unit was moving--they got a first report and then another at a later time and different location--but the original was still on the screen. They did not know if it was the same unit or another unit. A warrant officer operator was concerned: "The ASAS can't be operated with three to five terminals -- that's not enough." Similar points were made in response to interview question 100 (What is your overall impression of the system?), but only 37 percent of the comments were favorable while 23 percent were negative.

Opinions on the system were generally more negative during the CPX. Responses to the CPX Questionnaire are shown in Table 5. The first column for each day in the table shows the percentage of respondents who gave ratings of adequate or better in response to each item. The generally lower opinions undoubtedly resulted from the difference in the situations in which the interview and questionnaire data were obtained. During the CPX the operators were under greater stress and time pressure and had to use the system in a much more realistic manner than during training. As can be seen in the responses to item 2, ratings of adequate or better ranged from only 26 percent to 40 percent for adequacy of system operations. Also, system accuracy received relatively poor ratings. Adequate or better ratings in response to item 3 ranged from a low of 25 percent to a high of 36 percent of the operators. However, voice communications (item 6) fared much better, receiving adequate or better ratings from 75 percent to 82 percent of the respondents.

Adequacy of information received. The interview data showed that the operators were generally favorable about the information they received. In response to interview question 79 (How do you feel about the adequacy of information received?), 71 percent

TABLE 5

Percent of Operators Giving Ratings of Adequate or Better,
and Mean Ratings of Items on the CPX Questionnaire

Item	Day 1		Day 2		Day 3		Day 4	
	%	Mean	%	Mean	%	Mean	%	Mean
1. How adequate is the information you are receiving from the system?	50	3.40	26	2.68	40	3.20	32	3.14
2. How adequate is the operation of the system?	40	3.20	26	2.63	35	2.95	27	2.73
3. How adequate is the accuracy of the system?	30	2.70	31	2.75	25	2.85	36	2.95
4. How adequate is the A/N display?	80	4.20	79	4.11	90	4.10	95	4.09
5. How adequate is the SIT display?	60	3.70	39	3.44	55	3.40	59	3.50
6. How adequate is the voice communications?	80	4.00	76	4.12	75	3.90	82	3.86
7. How adequate is the organization of the player cell?	30	3.10	32	2.74	24	2.76	20	2.75
8. How adequate is the state of the CPX?	22	2.22	18	2.00	5	1.90	9	1.77
Number on shift		10		19		20		22

made positive comments while 23 percent made negative comments. Concern about missing information was expressed by many operators in response to interview question 81 (How do you feel about the interpretation of missing information?). Forty-six percent made comments indicating that they could deal with missing information compared with 23 percent who felt they could not. One analyst commented "It takes experience to know when information is missing. At times when airborne [sensor] platforms are not in the air due to weather, there are gaps in the information." One operator commented that things outside the JTFTB-A would affect whether the system worked: "The information is as adequate as the sensors that give it to them." Considerable concern with loss of information in case of system malfunction was expected. However, the responses to interview question 88 (How do you feel about the transfer of information to a manual TOC?) did not bear out the expectation. Sixty-nine percent made favorable comments concerning transfer while only 11 percent made negative comments. A senior analyst would have liked to have had a copy of the messages that went into the system to keep going if it had problems: "There should be a regular dump of the data base." This same analyst did not like the purge function because "somebody could get disgruntled and ruin the data base."

Adequacy of the information received was rated more poorly during the CPX. On the second day of the exercise only 26 percent of the operators felt that it was at least adequate (item 1, Table 5). The highest rating was given on the first day. However, even at the beginning of the exercise, only 50 percent of the operators felt the information received was minimally adequate.

Response time. A major concern throughout the test was expressed in responses to interview question 87 (How do you feel about the system response time to specific demands?). Only 26 percent of the operators made favorable comments while 57 percent made unfavorable ones. The major complaint concerned the time it took to redraw the map when new data were obtained. A modification to the terminal computer cut this time from 30 to 10 seconds during training. However, when a bigger, more complex map was installed for the CPX, the redraw time went back up to 30 seconds. Despite the redraw times, observations during the CPX indicated that operators actually spent very little time waiting on redraws. Hence, the complaints may have resulted more from minor frustrations than actual time lost. The problem appeared to be greatest when several broad range present queries were active for the same operator. However, this approach was considered a poor use of the system by most operators.

The time required to create queries bothered some operators. One stated that "the menus are very repetitious and very time consuming." A senior analyst pointed out, however, that most queries would be developed in advance of an operation, so the ongoing task of operators would be to make minor modifications and execute stored queries rather than create new ones.

Problems noted. There were three areas frequently mentioned by operators as causing problems during operations. Each of these will be discussed briefly.

(a) **Interference among functions.** All but one of the operators interviewed commented that functions interfered with each other (interview question 83, "Does the execution of one function interfere with the execution of another function?"). The consensus was summed up by one who stated very simply "You can't do more than one function at a time." By way of example, this operator offered: "While creating a query,

you must CANCEL the function and go back to DEFINE AOI." This kind of interference undoubtedly resulted in lost time as well as being a source of frustration for the operators.

(b) **Error correction.** Typographical errors, if noticed immediately, could be easily corrected by deleting the incorrect information and entering the correct information. If a frame was already completed and the DONE key pressed, then the usual procedure was to CANCEL the function and try it again. The correction of typographical errors with functions such as DELETE CHARACTER was rated as operating satisfactorily by 100 percent of the operators. The CANCEL function also was rated as operating satisfactorily by 100 percent of the operators. Many of the errors were not detected by the operators until the information wanted did not appear or the system sent an error message. Unfortunately, the questionnaire and interview did not directly ask about either of these situations. Observation of the operators indicated errors and the system response to them presented a continuing problem throughout the test. There were several comments indicating the kind of difficulties the operators were having. The EDR functions had some local error detection at the terminal: "You have to be very specific with fill-in-the-blank in an EDR or it will not accept what you write in." Other errors were transmitted to the correlation processor which would send a message back to the ALERT QUEUE, but as one operator put it: "The ALERT QUEUE does not get my attention." These messages stay in the queue so that the operators had difficulty determining which message referred to what function. Moreover, these messages from the processor did not give much information about why there was an error. As one warrant officer operator put it: "The error messages could not be understood." In one case, the message "ERROR LOCATION ERROR" for an EDR resulted in several attempts to change the information in the location field based on the advice of both other operators and test personnel. The actual difficulty was the scale factor for the distance put into the field LOCATION ERROR.

(c) **Organizational factors.** Some problems observed may have resulted from the manner in which the system was manned. Obviously, the system cannot be faulted for inadequacies in the operating organization. However, it is difficult to pinpoint exactly how the organization might have affected operations and impressions of system adequacy. This brief discussion is included here only to show that the personnel felt that organizational changes were needed. As can be seen in the response to item 7 of the CPX Questionnaire (see Table 5), adequate or better ratings of the organization of the player cell ranged from a high of 32 percent to a low of 20 percent during the four-day exercise. The problem was well stated by one of the test officers: "We tried to drop a system into an organization - we should identify the resources needed and develop the organization from that."

Terminal Functions

The dialogue between the operator and the system is carried on through the terminal. Hence, the terminal is really the heart of the system for the operator. What he or she can do with the system is limited by what information the terminal can provide and what functions it can perform, i.e., the dialogue characteristics. Therefore, the ratings of terminal functions are really ratings of the dialogue.

Display of information. The alphanumeric display was rated on seven information characteristics with six of these receiving adequate ratings from most operators with a

range of 78 percent to 84 percent (Table 6). The other characteristic, the incoming message indicator, was rated adequate by only 65 percent of the operators. It signaled there was a new message in the operator's queue by incrementing a message counter displayed on the second line of the display. It was easily overlooked, as indicated by one operator who said: "I would like for the ALERT QUEUE to have an indicator like ACKNOWLEDGE NEW DATA [i.e., flashing]."

Twelve of the 13 information characteristics of the situation [graphic] display were rated adequate by most operators with a range of 81 percent to 95 percent (Table 6). The exception was location of the cursor, which was rated adequate by only 64 percent. This lower percentage probably resulted because the cursor could be lost from the screen and because it moved in abrupt jumps instead of smoothly.

The alphanumeric display was also rated quite highly on the CPX Questionnaire, with ratings of adequacy or better ranging from 79 percent to 95 percent on the four days of the exercise (see item 4, Table 5). The situation display did not fare as well (item 5, Table 5). Adequate or better ratings ranged from a high of 60 percent to a low of 39 percent during the CPX. Respondents who gave poor ratings were not asked why the display was not adequate, so the reasons cannot be known for sure. However, the difference in the situations in which the Human Factors Questionnaire and the CPX Questionnaire were administered probably accounts for the difference. During the CPX, the system was being used in a more realistic manner. Shortcomings not noticed during training may have come to light.

Simple functions. The operators were asked about 43 simple functions on the terminal during the interview. The results are summarized in Table 7. For 35 of these functions, over 90 percent of the operators reported they worked satisfactorily. An additional five functions were reported as working satisfactorily by more than 80 percent. Of the remaining three functions, two--DIAGNOSTICS and INPUT MAP--were never used by an operator. The third, FAST MODE, was rated acceptable by 76 percent. The largest number of positive comments (21) was received for the numeric key cluster. The next largest number was 8 for the cursor control keys. The largest number of negative comments (24) was received for the DISPLAY ALPHA function. These negative comments mostly concerned the difficulty of telling which display was attached to the keyboard. One operator observed: "There should be a light under each screen to indicate which one is on." The next largest number of negative comments (18) was shared by ACKNOWLEDGE NEW DATA and the VOICE MODE switch. The ACKNOWLEDGE NEW DATA key had to be used whenever a present query updated the situation display to stop the new symbols from flashing. This would interrupt any other functions in progress. "I was locked out of the system for 20 minutes waiting while new data was coming in," complained one operator. Part of the problem may have been due to "bugs" in the routines that handled this function, as indicated by the operator who reported that characters deleted from the situation display reappeared whenever he pressed the ACKNOWLEDGE NEW DATA key. There was a general dislike for the way the voice communication system worked. As one operator put it: "I would like for it to operate like a telephone."

Complex functions. All 35 of the complex functions were reported as operating satisfactorily by 80 percent or more of the operators in the interview (Table 8). Thirty-three of these were rated as satisfactory by over 90 percent. The largest number

TABLE 6

**Ratings of Information Characteristics of Displays
(from Human Factors Questionnaire)**

Alphanumeric display--information characteristics				
Item	Number responding	Ratings of adequate or better		Mean rating
		Number	Percent	
System status	37	31	84	3.81
Attention-getting power of blink	37	31	84	3.97
Execution completed	36	30	83	4.00
Prompts	37	30	81	4.00
Execution underway	37	30	81	3.97
Error messages	37	29	78	3.95
Incoming message	37	24	65	3.51
Graphic display--information characteristics				
Unknown, enemy and/or friendly entities	37	35	95	4.19
Map scale	37	35	95	4.19
Time of last setting	36	34	94	4.19
Type of entity	37	33	89	4.08
Targetability	37	32	86	4.08
Control measures	37	32	86	4.08
Map location	37	32	86	4.05
Map width	36	31	86	4.08
Attention-getting power of blink	35	30	86	4.14
Map features	38	31	82	3.95
Location	37	30	81	3.95
Echelon	36	29	81	3.94
Location of cursor	36	23	64	3.58

TABLE 7

Frequency of Use, Operator Satisfaction, and Comments on Simple Functions From Human Factors Interview (arranged in descending order based upon Percent of operators indicating that they used a function five or more times)

Function	Number Times Used			% Satis- factory	Neg	Comments	
	1-2	3-5	5+			Neut	Pos
Simple Functions							
Display graphic	35	35	35	97	4	30	0
Display alpha	35	35	35	94	24	11	0
Enter	35	35	35	100	10	21	4
Done	35	35	35	100	9	21	5
Cancel	35	35	35	100	4	25	6
Acknowledge new data	35	35	34	100	18	13	4
Select map scale	35	35	34	97	8	25	2
Select map center	35	35	34	100	2	33	0
Home	35	34	33	94	13	16	6
Numeric key cluster	35	35	33	97	3	11	21
Clear	35	35	32	94	8	26	1
Cursor control keys	35	35	31	91	9	18	8
Tab	33	32	29	100	4	28	1
Log off	35	31	24	100	2	29	4
Scroll up	34	31	21	97	3	30	1
Prepare free text message	35	31	20	100	5	26	4
Voice mode switch	35	32	20	100	18	13	4
Scroll down	34	30	19	97	2	30	2
Move graphic	32	28	16	97	2	26	0
Write graphic	32	27	15	100	7	24	1
Delete character	25	19	10	100	0	25	0
Color keys	31	30	9	100	11	18	2
Plotter	15	12	9	80	13	6	2
Insert character	25	20	8	100	1	22	2
Normal character	27	20	8	96	2	25	0
2X character	28	22	8	100	9	19	0
Fast mode	25	18	5	76	16	7	2
Retransmit message	13	8	4	92	1	12	1
Erase line	18	9	2	89	2	15	1
Left front line	7	2	2	100	1	6	0
Erase page	12	6	2	92	0	11	1
Delete line	24	14	2	100	0	23	1
Normal background	16	3	1	100	1	14	1
Reversed background	16	3	1	100	2	14	0
Right front line trace	7	2	1	100	1	6	0
Insert line	22	22	1	100	0	21	1
Execute vector	4	0	0	100	0	4	0
End vector	4	0	0	100	0	4	0
Diagnostics	0	0	0	0	0	0	0
Front line trace off	5	0	0	80	0	4	0
Normal intensity	8	2	0	88	1	7	0
Low intensity	8	2	0	88	1	7	0
Input map	0	0	0	0	0	0	0

of positive comments was given to OFFSETTING DISPLAY SYMBOL. It also received six negative comments. The operators found that offsetting the symbols helped when the screen was crowded with entities: "This was helpful to make sense out of a cluttered screen." The difficulty with the function was the time it took to mark the symbol and then mark the offset position: "The screen gets cluttered quickly and the offset process is very tedious."

Two complex functions received eight positive comments in the interview - MODIFY QUERY and CREATE PAST QUERY. The MODIFY QUERY also received six negative comments, while the create function received nine negative ones. The MODIFY QUERY function allowed an operator to change a query that was already constructed instead of building one from scratch. This allowed the use of another operator's queries. It also allowed an operator to store a set of partially completed queries which could be modified to fit a specific situation. The MODIFY QUERY was an easy function to use: "The functions are so consistent that I have memorized what the frames are in the menus and I can press DONE until the frame in which I am interested appears." The query creation functions were liked for their straightforward menus: "It's easy when you follow the prompts to create a query." The negative comments came because the process could take a long time and because there could be up to 64 menus for selection: "Some menus repeat themselves too much." The past query function was seen as one of the most useful information gathering tools as the exercise developed. "A Past Query was helpful in making a record of what has happened in the past four to six hours."

The dialogue required in constructing queries caused some problems. Measures could not always be put into the forms in the way the operators were accustomed. It was pointed out that 24 hours had to be entered as 1 day, 00 hours, and north could not be entered as 360 degrees but had to be 0 degrees. When a query was started on a terminal that subsequently went down, it could not be deactivated by any other terminal. A warrant officer operator said he "would like an ID on the [displayed] symbols to match the A/N [alphanumeric] printout." According to a test officer, "present queries are really not that efficient in that they slow the machine down if there are a whole bunch [100 or more] that are active." He explained that this happens because each time a sensor report comes in it has to be matched against each active present query. The system is more efficient if an operator simply writes a series of past queries and periodically activates several of them to see if anything new has come up. The only way to review a query was to use the MODIFY function. As an improvement, "you need a summary of a query so you can tell something about it when you look at someone else's query."

The largest number of negative comments (19) in the interview was made about the DISPLAY QUEUE ENTRIES function. The operators found the queue procedures difficult to use, and some remarked they had missed messages or accidentally deleted them. As one said, "Once there were 24 messages in my OPERATOR QUEUE before I realized they were there." Another said, "The ALERT QUEUE does not get my attention." One suggested: "There should be a menu that comes up when displaying queue entry, allowing [the operator] to review or modify [the message]."

The next largest number of negative comments (15) were made about inputting control measures with the joystick. The major complaints were that it was a tedious, inaccurate process: "The process was not too precise - I have all the coordinates for FEBA [Forward Edge of the Battle Area], but can't remember where it was." Another operator said, "Control boundaries are extremely hard to draw, they need to be simplified." There was also concern that the color coding was not consistent with standard military maps: "The control boundaries were green - should be blue."

TABLE 8

Frequency of Use, Operator Satisfaction, and Comments on Complex Functions From Human Factors Interview (arranged in descending order based upon Percent of operators indicating that they used a function five or more times)

Function	Number Times Used			% Satis- factory	Neg	Comments	
	1-2	3-5	5+			Neut	Pos
Complex Functions							
Correcting typo	35	35	32	100	5	28	2
Storing, retrieving, or modifying AOI	35	35	31	100	5	28	2
Executing stored query	35	35	31	100	8	22	5
Reducing symbology on sit display	35	35	30	100	4	29	2
Displaying queue entries	35	35	30	100	19	15	1
Retrieving control measure from data base	34	32	30	100	5	29	0
Restoring symbology on sit display	35	35	29	97	6	29	0
Modifying stored query	35	33	29	100	6	21	8
Creating EDR	35	32	29	97	13	20	2
Reading location of cursor	34	34	28	100	6	23	6
Clearing all or part of current display	34	32	28	100	2	25	7
Creating present query	34	33	28	97	11	18	5
Inhibiting or restoring unit symbols on sit display	34	30	27	97	7	26	1
Offsetting displayed symbol	34	32	27	100	6	19	9
Dropping queue entries	35	31	26	91	9	24	2
Initializing	34	30	25	91	10	24	0
Displaying EDR or FDR on A/N display	32	29	24	100	2	29	1
Manipulating A/N display	35	33	22	100	6	26	3
Modifying EDR and FDR	33	30	22	100	3	29	1
Using logical zoom	32	26	21	100	5	23	4
Creating past query	33	25	19	97	9	17	8
Purging control measure from data base	29	25	19	97	3	26	0
Inputting control measure with joystick	32	29	18	81	15	17	1
Purging data EDR and/or FDR from data base and sit display	29	23	17	100	1	29	1
Creating aggregation	33	21	15	88	13	18	3
Sending sit display	27	22	14	96	4	21	2
Sending A/N display	26	19	10	92	7	19	1

Function	Number Times Used			% Satisfactory	Neg	Comments	
	1-2	3-5	5+			Neut	Pos
Displaying FDR on sit display	22	15	10	95	5	19	0
Modifying aggregation	24	16	7	96	3	22	0
Updating target status	26	14	7	100	5	25	0
Creating future query	25	13	5	96	2	22	1
Creating and sending cue photo message	26	14	5	96	7	21	0
Creating FDR	27	10	4	93	8	18	2
Creating and sending cue TACELINT message	18	8	3	94	5	13	1
Inputting control measure with graph tablet	3	2	0	100	1	5	0

Two complex functions received 13 negative comments each: CREATE EDR and AGGREGATION. Most of the complaints about dialogue had to do with these two functions. The EDR function used a mixed dialogue that consisted of some menus followed by a form filling frame. "I thought it was too time consuming - the menus need to be consolidated," said one operator and another found it was necessary "to be very specific with fill-in-the-blanks or it would not accept information." The form of numbers, placement of decimal points, and scale factors were among the things that had to be watched. There were several characteristics of entities that operators would like to have had in the EDR that were not there. One suggested "adding an annotation block to the EDR" to share information with other operators. The AGGREGATION function was not difficult but it was tedious. As one operator said, "It was easy when I read the prompts." Since each child had to be aggregated separately, it was easy to make a mistake in the middle of a series of entities: "I was unable to do this correctly." This function had problems in the early parts of the test, so that some operators may have been confused about how it worked by the time the CPX was held. Two of the operators who were asked to make aggregations by the test team during the CPX did not remember how to do it.

Terminal Design

Design of military equipment to meet human factors needs of personnel is governed by MIL-STD-1472B.²² This document compiles relevant human factors information into a series of tables and charts to cover all of the types of man-machine systems being acquired by the Department of Defense at the time of its publication. An additional standard, MIL-STD-1280,²³ specifically covers the design of keyboards. The STANDARD in effect at the time this research was done had a section on consoles, but the recommendations were based mainly on research with radar displays and discrete control systems (e.g., knobs, dials, and switches). Because video display terminals are used in a qualitatively different way from these early types of consoles, many of the features of the JTFTB-A terminal are not covered by the standards.

In general, the terminal provided a workable user-computer interface with the JTFTB-A system. It had many problems that made the operator uncomfortable, made some tasks more difficult to execute than they might have been, and made some functions fairly difficult to learn. There was, however, no evidence that any feature of the terminal would prevent an operator from carrying out any of the intelligence tasks so far identified in the documentation or by the test participants.

Keyboard. A view of the terminal keyboard is shown in Figure 1. The scale in the photograph is in centimeters. Questionnaire results are summarized in Table 9. Over 80 percent of the operators gave adequate ratings to the terminal for size of labels, control type, control shape, correct labels, size of controls, understandable labels, location of labels, and reach distance to noncritical controls. All of these features also met the applicable standards. Lower ratings were given to critical control location with only 41 percent of the operators rating it as adequate. The location of controls on the function

²²US Department of the Army, op. cit., 1974

²³US Department of the Army, op. cit., 1969.

INIT		QUERY		JMWACC MSG		PREP MAP		DATA	
LOGON		CREATE QUERY		PREP CUE FMDT	PREP CUE FMDT	PREP CUE FMDT	PREP CUE FMDT	PREP CUE FMDT	PREP CUE FMDT
		GET CHGEN IR							
LOGOFF		END CAL DTP		PREP END MSG					

DISPLY CTRL		EDR/FDR		CM		FREE		MAP		CURSOR		DATA	
MOVE A/N TO SIT		SEND A/N DISPLY		CREATE EDR		CREATE FDR		INPUT CTRL MEASUR		INPUT MAP DRAM		READ CURSOR POSN	
RETURN A/N FR SIT		SEND A/N FR DISPLY		AGGRE- GATE		GET EDR/ FDR		GET CTRL MEASUR		SELECT MAP SCALE		DISPLAY CURSOR PARAMS	
RECALL SIT DISPLY		MODIFY AGGRE- GATE		MODIFY EDR/ FDR		PURGE EDR/ FDR		PURGE CTRL MEASUR		SELECT MAP CENTER		SELECT CURSOR PARAMS	

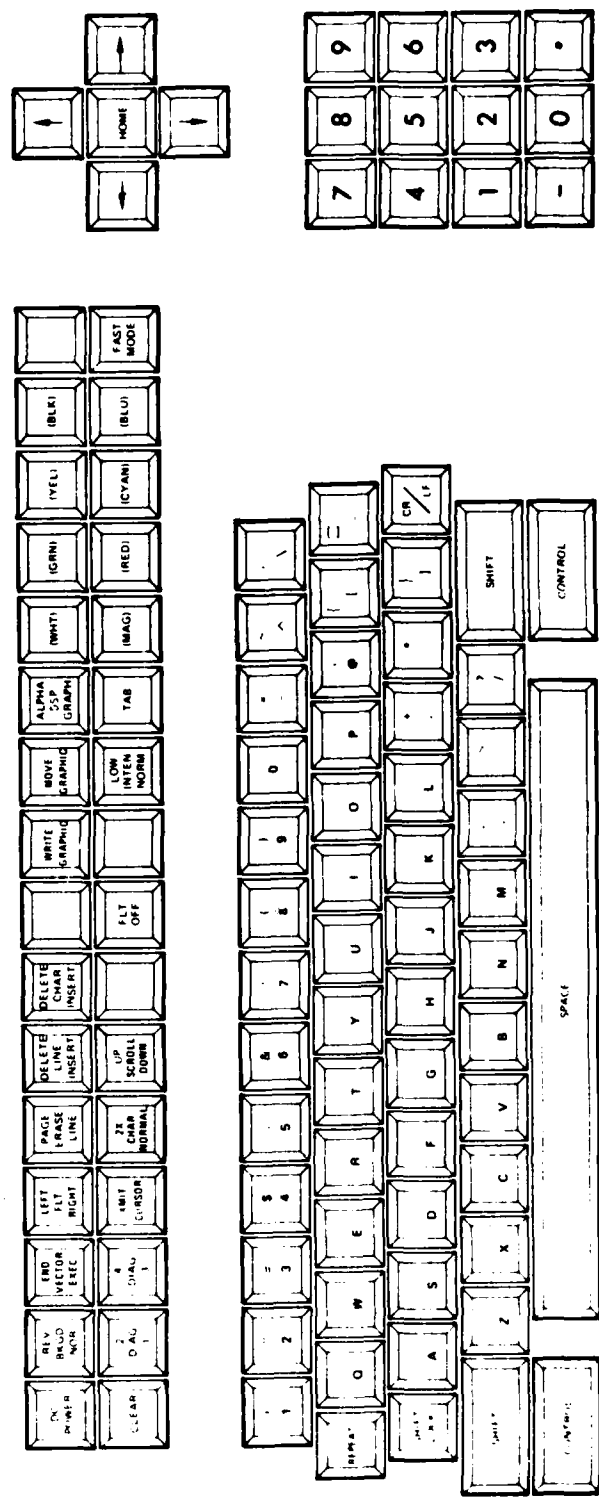


Figure 1. JTFB-A terminal keyboard

TABLE 9
Summary of Control Layout Responses
From Human Factors Questionnaire

Item	Number Responding	Rated Number	Adequate Percent	Mean Rating
Control layout				
Size of labels	38	37	97	4.29
Control type	37	34	92	3.95
Shape	38	34	89	4.05
Correct labels	38	34	89	4.13
Size	38	32	84	4.00
Understandable labels	37	31	84	4.05
Location of labels	38	31	82	3.92
Noncritical control reach distance	37	30	81	3.81
Control visibility	37	29	78	3.95
Function grouping	37	29	78	3.76
Absence of unrelated or confused markings	36	27	75	3.89
Noncritical control location	37	27	73	3.68
Spacing between controls	38	26	68	3.68
Control angle of view	37	25	68	3.73
Keyboard feel	38	24	63	3.61
Critical control reach distance	37	19	51	3.11
Critical control location	37	15	41	3.00

keyboard was not liked by several operators. Of particular concern was the location of two frequently used controls, ENTER and DONE, on the top row of the keyboard. Thirty of the 35 operators suggested changes in the location of controls when interviewed. One even provided the test team with a drawing for a new keyboard. Some examples of the suggested changes were "PICK, TAB, and CLEAR should be in the ADMIN section"; "Relocate ADMIN section closer to numeric pad"; and Relocate TAB on A/N keyboard like regular typewriter."

Critical control reach distance was rated as adequate by 51 percent of the operators. The location of the joystick and the top three rows of function keys are beyond the reach of a 5th percentile male in a sitting position as required by the standard. This includes the ENTER and DONE keys. The reach distance was calculated from the photographs and then applied to the chart on page 530 of Van Cott and Kinkade.²⁴ The distance to the joystick is 105 cm while the reach range at a 30 degree angle is 76.2 cm. "There is lots of reaching to select items [using the keyboard]," commented one operator and another said, "The joystick is to far away; it's awkward to reach. Move it nearer the function keyboard." These controls can be reached by leaning over the keyboard or by moving closer to the terminal, but both solutions make it difficult to see the situation display at the operator's right. Moving the operator closer to the screen is hampered by the protruding keyboard shelf and the limited leg room under the console. Leaning over also has the disadvantage of making the operator uncomfortable and could be fatiguing over an extended period of time.

The alphanumeric keyboard conformed to MIL-STD-1280 except for the operation of the shift key. However, the flat-topped function keys are contrary to the recommendations of the standard. Also, the power-on light looks like a key, and it is white instead of the required green.

Workspace. Operator ratings of workspace, summarized in Table 10, were generally adequate. However, test personnel observed that the terminal keyboard and writing

TABLE 10

Summary of Workspace Ratings
From Human Factors Questionnaire

Item	Number responding	Ratings of adequate of better		Mean rating
		Number	Percent	
Leg room	38	37	97	4.24
Seating cushion	34	31	91	4.09
Seating backrest	35	30	86	4.06
Elbow room	38	32	84	4.00
Seating horizontal adjustment	34	28	82	3.94
Seating vertical adjustment	35	27	77	3.74
Storage room	37	13	35	2.92

²⁴Van Cott & Kinkade, op. cit., 1972.

surface were too high above the floor for short operators unless special chairs were provided. The standard requires that both of these should be approximately 65 cm above the floor to accommodate the 5th percentile male using a standard adjustable chair. The JTFTB-A surfaces were 84 cm above the floor, which meant short operators worked either with their arms at shoulder level, or, if they were able to adjust the chair, with their feet dangling in the air. No direct rating of this aspect of the terminal was made and 77 percent of the operators rated the vertical seating adjustment as adequate. One smaller operator remarked, "There needs to be a foot rest for short operators." Other comments in the interviews were: "It's too high in the air - get it at typing level," and "The chair should be adjustable so the operator's feet don't dangle."

Various other dimensions of the terminal were found either in conflict with the standard or disliked by the operators. The width of the writing area is 54 cm, which is less than the 61 cm minimum recommended by the standard. Eight operators complained that the terminal was difficult for lefthanded persons to use: "As a lefthander, I find the joystick very awkward [to use]." The space under the keyboard and writing area is insufficient for large operators because there is only 42.4 cm clearance from the keyboard lip to the panel while the standard requires a minimum of 46 cm. One operator found this a problem: "I knock my knees under the A/N console when I stand up." The standard also requires a kick-hole clearance of 10 cm in the vertical and horizontal dimension, but the terminal has one that measures 14.9 cm high by 7.0 cm deep. This probably caused one operator to complain, "I always scrape my boots on the console."

Joystick. In addition to the problem of locating the cursor, the operation of the joystick itself was rated down by many operators. Control of the cursor for the situation display, which was done mainly with the joystick, was rated adequate or better by only 33 percent of the operators. When asked to comment about the joystick in the interview, 77 percent of the operators made comments that were classified as negative while only nine percent made positive ones. The difficulties came from two sources. First, many of the operators were unaware that the MOVE GRAPHIC function put the joystick into a pixel move mode which caused the cursor to move in small steps. Only nine of the operators did report knowing about this. Those who did know were using it in a character-move mode which caused it to take large jumps. Second, the cursor was difficult to control for fine movements. The rate-control design had a very steep slope which meant that the cursor would move very little or not at all with light pressure, while a slight increase would send it racing for the edge of the screen. This caused difficulties: "I lost the cursor when moving it with the joystick." Sometimes the cursor would drift because the control did not return to a zero position: "...and even the thumbwheels on the joystick wouldn't adjust it." Another operator commented: "The joystick is the pits - I would prefer a [track] ball control." Perhaps the experience with video arcade games had made today's a soldier a critical judge of position controls.

Alphanumeric display. Four of the seven characteristics of the alphanumeric display were rated adequate or better by at least 80 percent of the operators (Table 11). Only 65 percent rated the absence of glare as adequate, however. The flat glass shields placed in front of each screen to prevent classified information from being compromised was the location of the glare. Because the displays are tilted back at an angle of 11 degrees from vertical, they pick up reflections from the overhead lights. Operators commented: "The glare was bad - it was easy to get eyestrain," and "There was too much glare. I had a headache all the time after using it." Absence of flicker was rated as adequate by 78 percent of the operators and no comments were made about this. The alphanumeric

TABLE 11

Ratings of Display Characteristics
(from Human Factors Questionnaire)

Alphanumeric display--display characteristics

Item	Number responding	Ratings of adequate or better		Mean rating
		Number	Percent	
Display brightness	37	36	97	4.24
Viewing distances	37	32	86	4.08
Legibility	37	31	84	4.11
Angle of view	37	30	81	3.95
Absence of flicker	37	29	78	4.00
Control of cursor	35	24	69	3.71
Absence of glare	37	24	65	3.68

Graphic display--display characteristics

Symbol clarity	36	35	97	4.22
Color differences identity	36	32	89	4.08
Display brightness	36	31	86	4.06
Intensity differences	36	31	86	4.08
Absence of flicker	36	29	81	3.92
Legibility	37	30	81	3.95
Angle of view	36	27	75	3.83
Absence of glare	37	22	59	3.49
Control of cursor	36	12	33	2.92

display had a full range of controls (e.g., brightness, contrast, focus) for the operator to adjust as required by the standard.

The angle of view was rated adequate by 81 percent of the operators, but at a viewing distance of 75 cm the alphanumeric screen presents the 5th percentile male with viewing angles of 0.0 to 15.6 degrees, which is above the preferred range of -30 to 0 for critical displays. A visiting general commented: "The small print on the A/N display is hard to read with bifocals [without tilting my head back]," while an operator said, "I always have to tilt my head to see the OPERATOR QUEUE." The character size on the alphanumeric display is 2.82 mm high by 2.00 mm wide, which presents an angle of view at a 75 cm viewing distance of less than the 15 seconds of arc required by the standard. Most operators did not find this to be a problem, as 86 percent rated the viewing distance and 84 percent rated the legibility of the display as minimally acceptable. There were some complaints in the interviews about the small character size, however. Four operators told the interviewer things like "The letters on the A/N display are too small."

Situation display. The ratings of the situation or graphic display were generally at least adequate including symbol clarity, color differences identity, display brightness, intensity differences, absence of flicker, and legibility. Only two characteristics, absence of glare and viewing angle, were rated adequate by fewer than 80 percent of the operators. The source of glare is the same as the alphanumeric display and the comments were similar. Angle of view was rated adequate by 75 percent of the operators. The vertical viewing angle was similar to the alphanumeric display because the center lines are at the same height. The -4.2 to 19.6 degree angle of the situation display falls outside the recommended range. The operator usually sits on the left side of the terminal to operate the keyboard which puts the display at a 30 degree angle to the right. While this is within acceptable viewing angles for critical displays, it does present a severe parallax problem when another person tries to point to something on the display. In the interview, one operator commented: "By moving the graphic screen to an angle, the operator would be able to view the left side of the screen much more easily." Another suggested: "The keyboard should be centered so there is an equal viewing distance to the screen."

Working Environment

Physical environment. Operator ratings of the environment are shown in Table 12. However, since the terminals were not operated in the shelters for this test, the ratings of

TABLE 12

Summary of Environment Ratings
(from Human Factors Questionnaire)

Item	Number responding	Ratings of adequate or better		Mean rating
		Number	Percent	
Ventilation	37	35	95	4.08
Vibration	36	34	94	4.11
Noise	37	32	86	3.89
Illumination	37	28	76	3.76
Temperature	37	27	73	3.73

the environment are of limited use. Measurements inside the three shelters housing the system equipment indicated the operators might find them too cold and too noisy. Table 13 shows the temperature, humidity and sound levels measured on three days while the system was operating. All of the relative humidity measures were acceptable, being above the minimum of 15 percent required by the standard for semipermanent shelters. All of the temperatures in the processor shelter were unacceptable, being below the 65°F (18°C) minimum required. These temperatures ranged from maximums of 54.9°F (12.7°C) to 64.2°F (17.9°C). The communications shelter maximums were below the minimum on two of the three days. The effect of the low temperatures in both shelters was aggravated by a design in which the airconditioning system discharged cold air directly on the operators. This type of design is specifically prohibited by the standard. The standard requires a maximum noise level of 68 dB(A) for an activity where "frequent telephone use or frequent direct communications at distances of up to five feet is required" and a maximum of 75 dB(A) where occasional communications of this type is required. The minimum noise level measured in the processor van shelter during the three days was 77 dB(A) which exceeds both conditions. The minimum noise level in the communications shelter was 68 dB(A) which exceeds the stricter standard. While in these shelters, the observer noted that the operators had a great deal of difficulty talking on the telephone. They also had to shout at each other to be understood even when they were standing very close together. The environmental measures in the remote display station shelter were acceptable in every case. The equipment was turned on but it was not being used for anything, so it is not clear that the same desirable conditions would be obtained with six terminals and their operators in action.

TABLE 13
Environmental Measurements of JTFTB-A Shelters

Location	Number of Measurements	1	Day 2	3	Range Minimum	Maximum
Mean Dry Bulb Temperature (Celcius)						
Central Processor	3	17.0	15.4	16.4	12.7	17.9
Communications	2	20.4	14.2	12.6	12.2	20.4
Remote Display	2	22.4	20.6	20.9	20.2	22.7
Mean Relative Humidity (percent)						
Central Processor	3	48	49	53	42	56
Communications	2	69	51	56	48	72
Remote Display	2	56	63	72	56	72
Mean Noise Levels (dB(A))						
Central Processor	3	78	78	78	77	80
Communications	2	72	72	70	68	74
Remote Display	2	54	63	63	62	64

Physiological problems. A summary of the physical complaints acquired during the shifts for the CPX is shown in Table 14. The most common complaints at the end of shifts were being tired, 82.9 percent, and being hungry, 44.7 percent. Complaints reported by at least 20 percent of the operators were headaches, eye or vision problems, neck or shoulder stiffness, thirst, and back problems. Because many of the complaints were also reported at the beginning of the shift, the number of people who got the complaint during the shift is shown in the table. Getting tired or drowsy still led the list at 42.1 percent followed by hunger at 35.5 percent. Four other complaints were picked up by more than 10 percent of the operators during the shift: neck or shoulder stiffness, eye or vision problems, headaches, and back problems. The largest number of complaints were picked up by operators on the second day of the exercise with a rate of 2.29 per person. The fewest was 1.71 on the first day. The observers obtained the complaint information by interview and it appeared that many of the operators were not feeling well during parts of the exercise.

TABLE 14
Percentage of Operators Reporting a Specific Complaint
Who Had Not Reported it at the Beginning of the Shift

Complaint	Full Exercise	Day			
		1	2	3	4
Tired, drowsy	42.1	38	41	55	33
Hungry	35.5	48	29	30	33
Neck or shoulders	23.7	24	24	20	28
Eye or vision	22.4	24	29	15	22
Headaches	21.1	14	29	15	22
Thirsty	17.1	5	18	15	33
Back	17.1	10	24	20	17
Cold/flu	6.6	0	12	5	11
Arms	6.6	10	6	5	6
Wrist and fingers	6.6	0	18	5	6
Stomach	5.3	0	6	0	6
Number of responses	76	21	17	20	18

Suggested Changes

A number of suggestions for changes were mentioned in the earlier discussions but will be reviewed again briefly here. Among the more frequently mentioned changes were the need for some kind of signal to alert the operator to important incoming information, movement of the joystick to make it easier to reach, and moving the ENTER and DONE keys to the front of the keyboard. A means of correcting errors more simply was also a commonly expressed need. One suggested solution was to add a "backup" function which would allow the operator to return to a previous frame without having to CANCEL and start over. The need for clearer error messages was also expressed.

The addition of something such as a "hold key" was suggested as a means to allow the operator to leave a function and come back to it at the point in the dialogue when he/she left the function. This would alleviate the need to CANCEL and start over if something more important had to be done.

Software change suggestions involved simplifying menus, adding default selection, and providing a means to skip over unwanted frames. An interesting software addition of a "calculator mode" was suggested to do tasks such as converting map coordinates. One operator brought a programmable calculator for his own use in converting UTM to latitude-longitude and vice versa.

Numerous suggestions for changes in the construction and layout of the terminal were made. However, most of these would probably have not been made if the terminal design had conformed more closely with the standards for such equipment.

Several operators stated a need for making some of the functions less tedious and time consuming. The AGGREGATION, PURGE, and TARGET DESIGNATION functions in particular were cited. Operators disliked using these functions because of the time required if several entities had to be picked. The current procedure required each entity to be picked separately. A procedure which would permit the picking of all the entities before further processing was suggested by many as a solution.

Two other suggestions of a minor nature were made by a number of operators. One was an indicator which would inform the operator which display was "attached" to the keyboard. The other was for a volume control for the headsets.

Summary, Observer Comments, and Conclusions

A major concern in evaluating human factors characteristics of a complex system such as the JTFTB-A is how well it performs the job it was designed to do. A system can be very good from the standpoint of how comfortable the terminal is to use or how "user-friendly" the dialogue is rated and yet that system might not serve user needs at all. Conversely, a system might have many problems on both of these aspects and still perform its job adequately. Obviously, it is better to have a system that works than one that is easy to use but doesn't; so engineering and programming problems must be dealt with first in the development process. Human factors studies of the type described here and, even more desirably, ones that make more direct, specific tests of various features, can then point the way to make future versions of the system that both work well and are easy to use.

The lack of a concept of how the system was to be employed or any specifications of its operational capabilities made evaluation of all objectives in the field test, not just the human factors portion, difficult to carry out. The operators in this test were not well trained, so it was not possible to get direct information even on how well the system was capable of functioning in specific cases. Despite these limitations, the system could be compared with some "baseline" cases. Most operators and some test personnel had had experience with manual intelligence systems in the field against which they could judge the CPX performance. There was also a notion of an "ideal ASAS" based on experience with other automated systems that the operator could use for comparison. Finally, many of the human factors characteristics could be compared to military standards or good design practices. Such implied comparisons cannot be used to say that a system is good

but do provide good information on what to evaluate more closely in the next test and what design changes should be considered.

Most of the operators thought that the system would be superior to the manual methods now being employed by intelligence units. They liked the rapid processing of messages and the ability to get information on a map display quickly and accurately. Their difficulty in getting it to work in the CPX and the time it took to complete many functions were seen as negative qualities. They were concerned about their minimal training and lack of knowledge about the system. The opinions of the system dropped considerably during the CPX when the operators were mostly unsuccessful in tracking the enemy forces.

The operators were trained on the use of specific functions, so these could be evaluated. Most of this data were collected shortly after training, before the operators had had much experience doing anything but training exercises. As the observers got a better understanding of the system by watching it in use and reviewing the technical materials, it became clear that many of the operators' problems were the result of not understanding how to do things rather than any deficiencies in the system design. Thus, their comments must be viewed from a perspective of learning to use the system functions at a mechanical level rather than from one of an experienced person using those functions to do a task.

Almost everyone who has had contact with the operator terminal has suggestions on how to improve its design. For example, the first group of operators who were trained at the contractor's facility put together an 11 page list of "system enhancements." Many of these same "improvements" were brought up during the interviews with the current test participants. It is not possible to fully evaluate the merits of any of the suggested changes with the limited amount of testing done so far. Many seem to fall into the category of an alternative approach to doing the same task rather than an improvement in the performance of the user-system combination. Most of the operators had not received enough training or experience to know how to carry out some tasks that they wanted to do, and so suggested a "function key" that would do that task. While such functions could facilitate specific tasks, the overall effect might not improve system performance.

The characteristics of the alphanumeric display which was used to conduct the dialogue and receive messages were rated favorably by most operators. One exception was the signal that the operator had a message. This alert signal, incrementing a counter on the display, was missed by many operators when they were involved in another activity. The characteristics of the situation display, which presented the location of units on a map background, also were rated favorably by most operators. The one exception for this display was the cursor, which the operator could "lose" if it was moved to the edge of the display.

Individual functions were rated highly by most operators although there were many suggestions about how to change them. The numeric key cluster was considered a very useful feature, while the joystick was not rated as adequate by many because of the large jumps it caused the cursor to make on the situation display. Some operators were aware they could correct this latter problem by executing a function which would switch to a smooth movement mode. The operators also wanted some sort of indicator on the terminal to tell them which display was attached to the keyboard at that time.

Complex functions like the ones used to build queries were rated highly by the operators, but again they had many minor complaints and suggestions for improvement.

Their biggest concern was the time it took to go through the functions and they suggested many shortcut procedures such as additional functions or dialogue frame skipping procedures. The prompting form of the dialogue made it easy to go through most functions provided the operator knew which function was needed to carry out a task. A minor difficulty was that some seemingly reasonable entries such as 2400 hours or 360 degrees would not be accepted. Query building and modification functions were rated as tedious by some. A suggested improvement was a listing of the selections and defaults at the beginning of the procedure. The aggregation function was considered too difficult to use during the pressure of an operation. Some means to pick all of the "children" for a "parent" with a single command sequence was suggested by more than one operator.

The design of the terminal was compared with current human factors standards. It was adequate in most respects. The large displays and the color coding on the situation displays made information readily available to the operator. All of the controls needed by the operator were on the shelf in front of the displays and a secure voice communication system let the operators talk with one another and with other elements of the system.

There were several shortcomings in the physical configuration of the terminal housing, however. It was not designed to work with the range of adult male sizes required by military standards. Also, this was a problem for some of the operators in this test who were short females and had difficulties in reaching some parts of the keyboard. The terminal is too high off the floor for short operators unless an easily adjustable chair with a heel catch is provided. The space for legs and shoes under the terminal was insufficient for taller operators. The small size of the characters on the alphanumeric display and the distance the operator had to sit in front of the terminal made that screen difficult to read for some. This sitting position also put several important function keys and the joystick out of reach of shorter operators unless they leaned forward. When this was done, the problem of having to look at the situation display at an angle to the right was aggravated. This angle of view made it difficult for another person to point to something on the situation display so that the operator would know what was being indicated.

The control arrangement was not liked by some operators. Some of the most frequently used were not only located on the top row of keys which was out of reach for some operators, but also were located apart from the numeric cluster with which they were most frequently used. Several keys had functions that duplicated other procedures within functions or even other keys. Most operators who suggested changes wanted the duplicate functions removed to simplify the keyboard. The alphanumeric display was considered adequate except for a problem of glare on the faceplate. This same problem was reported for the situation display. Both screens are located in a position that would make a short operator have to look above the preferred line-of-sight. There were some complaints about the color coding on the map display and there is no way for the operator to adjust the color or contrast of the display.

The terminal is awkward for lefthanders since the writing surface and joystick are to the right of the keyboard. The writing surface is slightly smaller than the standards require, and like the keyboard, is too high above the floor for the chairs provided. The operators were concerned that there is no volume control on the headsets. Measurements of the temperatures and noise levels in the equipment shelters which housed the central processor and communication equipment showed these were both too cold and too noisy according to standards. Cramped working space and the need to type would mitigate against using warm clothing. Ear protection might be difficult because there is a constant need to use the telephone in these areas.

The operators were questioned about any physical complaints during the shifts for the CPX. Several common symptoms such as headaches, neck and shoulder stiffness, and vision or eyestrain were reported. Such complaints could indicate the seating posture at the terminal and the long sessions at the video display are fatiguing. They could also indicate the operators were under a lot of stress during the exercise.

During the CPX, it was the observers' impression that the JTFTB-A system had the capability to do almost everything the operators wanted it to do. This is not to say that a particular operator who wanted to do a specific thing either was able to do it or even had been trained to do it. Rather, it means that when an operator brought up a need for a certain kind of information, either another operator, a member of the test staff, or one of the contractor support personnel usually were able to find a way to accomplish it. It is not clear whether the operators could be trained to do some of these specific tasks reliably or whether these tasks could be done in an efficient manner.

The operators, both during the testing of single functions and during the CPX, had learned to operate only some of the functions, and in some cases they did not know how to do all of these well. In fact, they still were in the process of discovering how to use the system to obtain and analyze intelligence information during the CPX itself. A warrant officer serving as the supervisor told an observer that on one shift he "didn't even work the CPX" but rather spent his time "punching buttons" to discover how to write queries that could be used to track a particular kind of unit. In another case, an operator spent most of the night trying to work out a method to deal with the large number of radar entity data records presented on the situation display. The aggregation function took too long to keep up with the incoming information, but by purging all of the entities on the screen and replacing them with a single compound element symbol, it was possible to stay updated. This also required a use of past queries that had not been covered in the training.

The lack of good documentation aggravated the problem of using the system. The manuals were arranged in a tutorial format which did not lend itself to looking up specific information. There were few indexes in the manuals and only brief tables of contents. It took almost an hour of the combined efforts of two senior operators, a test observer, and a software support specialist to determine how to make a relative time entry in a past query which would retrieve only those entities reported in the past six hours. Some sort of ready reference could be provided at each terminal to cover those functions that the operators do not use frequently enough to remember well. Alternatively, this information could be made available through a "help" function in the system.

The difficulties operators had getting the system to give them what they wanted quickly disenchanted many. They would give up trying and leave the terminal for extended coffee breaks. Since problems are going to be part of any new system, it is essential to keep the operators from giving up. Those operators who were able to get help kept trying to do things and eventually were able to do most of the things they wanted. This indicates that someone who is knowledgeable about the terminals and the system always should be accessible when testing. The test team personnel were able to perform some of this function once they became proficient with the terminals, but it still would be desirable to have a software specialist in the terminal area whenever testing or training is in progress.

The feedback to the operators from the system was one of its weakest links. When an operator did not receive the information expected, it was virtually impossible to be certain what had happened. Functions like queries should present a concise restatement

of what was selected when the preparation is completed or when it is brought back for modification. A hard copy of this summary could then be checked by supervisors if problems have occurred. The error messages represent a primary type of feedback and many were not easy to understand, which sometimes led to operators making changes in already correct information. Error messages from the processor were often missed because the alert queue increment was not noticed. An attention getting signal such as flashing characters should be used since undetected errors are bound to affect operation capabilities at times. Good error messages should give all of the problems that the processor can detect and should refer the operator to the appropriate place in the documentation for additional help. The repetition of this much information can be tedious for commonly made errors, so the designers might consider using a multilevel error reporting system which gives only abbreviated error messages which can be expanded at the operator's request.

Another problem for the operators was the time it took to carry out many common operations. For example, aggregation, purge, or target designation required a sequence of key strokes for each entity involved in addition to the time it took to position the cursor over an entity. Any operation that required regeneration of the display could take an additional 30 seconds or more if there was a complicated map in the system. This delay was a nuisance when the operator wanted only a single piece of information like the cursor coordinates. More important is that the rate at which an operator performs commonly used functions is going to set the limit on how much information an operator can handle in a given period. This in turn sets the limits on how much information can be processed by the system as a whole with a given set of terminal assignments. Alternatively, reliable information on how fast these functions can be carried out could be used to predict how many operator terminals will be required. It appears that considerable simplification might be built into many common functions. Global picking of all entities of a given type in the area of interest for target designation or aggregation would be one possibility. Another is to indicate the cursor coordinates on the alphanumeric screen, which would eliminate the need to regenerate the situation display.

A potentially serious problem was uncovered during the single function testing phase which involved the possibility that more than one operator would modify the same entity data record during the same time period. This would result in only the version posted last being saved, and there would be no indication to the other operators that their changes had been lost. Discussion of this problem with the test personnel led to the suggestion that strict operating procedures could prevent any problems with duplicate changes. This does not seem likely because the dispersed location of the terminals would make it difficult to monitor all of the operators. In addition, the time pressure on the operators to get the job done would make it virtually impossible to specify the mutually exclusive areas of responsibility necessary to prevent duplication. It is likely that there are other possible operations where the work of one operator would undo that of another without either of them being aware of it. A fairly extensive study of the threats to the integrity of the data base needs to be undertaken. This would allow methods of protection to be devised based either on internal system controls or on supervisory methods.

The JTFTB-A represents an excellent vehicle for testing the human factors elements in intelligence decision aiding systems. Future tests need to incorporate specific experimental tests of the human factors issues raised in this first field test.

HUMAN FACTORS CHARACTERISTICS OF THE JOINT TACTICAL FUSION TEST BED: FIELD TEST 467 RESULTS

REFERENCES

- Cooper, R. G., Marston, P. T., & Kubala, A. L. Human factors in automated C³I systems (FR-MTRD(TX)-81-13, Draft). Alexandria, VA: Human Resources Research Organization, March 1981.
- Goldstein, R. C. The substantive use of computers for intellectual activities (MAC TM 21). Cambridge, MS: Massachusetts Institute of Technology, April 1971. (DTIC No. AD 721 618)
- Haynes, A. M., LaPointe, P. L., Cooke, H. L., & Underwood, J. A., III. Tactical fire direction (TACFIRE) operational test III (TCATA Test Report No. OT 056). Fort Hood, TX: TRADOC Combined Arms Test Activity (TCATA), August 1978.
- Institute for Defense Analyses. Computers in command and control (TR 61-12). Washington, DC: Research and Engineering Support Division, November 1961. (DTIC No. AD 251 997)
- Marston, P. T., Kubala, A. L., & Cooper, R. G. Human factors considerations in the battlefield exploitation and target acquisition (BETA) system: A preliminary evaluation (FR-MTRD(TX)-81-12). Alexandria, VA: Human Resources Research Organization, February 1981.
- Martin, J. Design of man-computer dialogues. Englewood Cliffs, NJ: Prentice-Hall, 1973.
- Montgomery, C. A., Thompson, J. R., & Katter, R. V. Human processes in intelligence analysis: Phase I overview (Research Report 1237). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences, 1979.
- Murray, W. E., Moss, C. E., Parr, W. H., & Cox, C. A. A radiation and industrial hygiene survey of video display terminal operations. Human Factors, 1981, 23, 413-420.
- Ramsey, H. R. & Atwood, M. Human factors in computer systems: A review of literature (Technical Report SAI-79-111-DEN). Englewood, CO: Science Applications, Inc., September 1979. (DTIC No. AD A075 679).
- Smith, M. J., Cohen, B. G. F., & Stammerjohn, L. W., Jr. An investigation of health complaints and job stress in video display operations. Human Factors, 1981, 23, 387-400.
- Stammerjohn, L. W., Jr., Smith, M. J., and Cohen, B. G. F. Evaluation of work station design factors in VDT operations. Human Factors, 1981, 23, 401-412.
- TRW Defense and Space Systems Group. BETA operator positional handbook (CDRL A009, FSCM No. 11982). Redondo Beach, CA: Author, April 1, 1980.

- TRW Defense and Space Systems Group. BETA software architecture and process flows (SS22-47B, FSCM No. 11982). Redondo Beach, CA: Author, September 28, 1979.
- TRW Defense and Space Systems Group. System specifications for BETA test bed (SY16-12-C, FSCM No. 11982). Redondo Beach, CA: Author, January 26, 1979.
- US Army Combined Arms Combat Development Activity. Architectural concept for 1985 for U.S. Army Tactical Command, Control, Communication and Intelligence (C3I) (ACNO 52686). Fort Leavenworth, KS: Author, 1978.
- US Army Training and Doctrine Command Combined Arms Test Activity. TCATA Test Report FT 467: Joint Tactical Fusion Test Bed-Army (JTFTB-A) (RCS ATCD-8). Fort Hood, TX: Author, May 1982.
- US Department of the Army. MIL-STD-1280: Military standard keyboard arrangements, January 1969.
- US Department of the Army. MIL-STD-1472B: Human engineering design criteria for military systems, equipment and facilities, December 1974.
- US General Accounting Office. Tactical operations system development should not continue as planned (LCD-80-17). Washington, DC: Author, November 20, 1979.
- US House of Representatives. Department of Defense Appropriations Bill, 1981 (HR 96-1317). Washington, DC: US Government Printing Office, September 11, 1980.
- Van Cott, H. & Kinkade, R. G. (ed.). Human engineering guide to equipment design (rev. ed.). Washington, DC: US Government Printing Office, 1972.